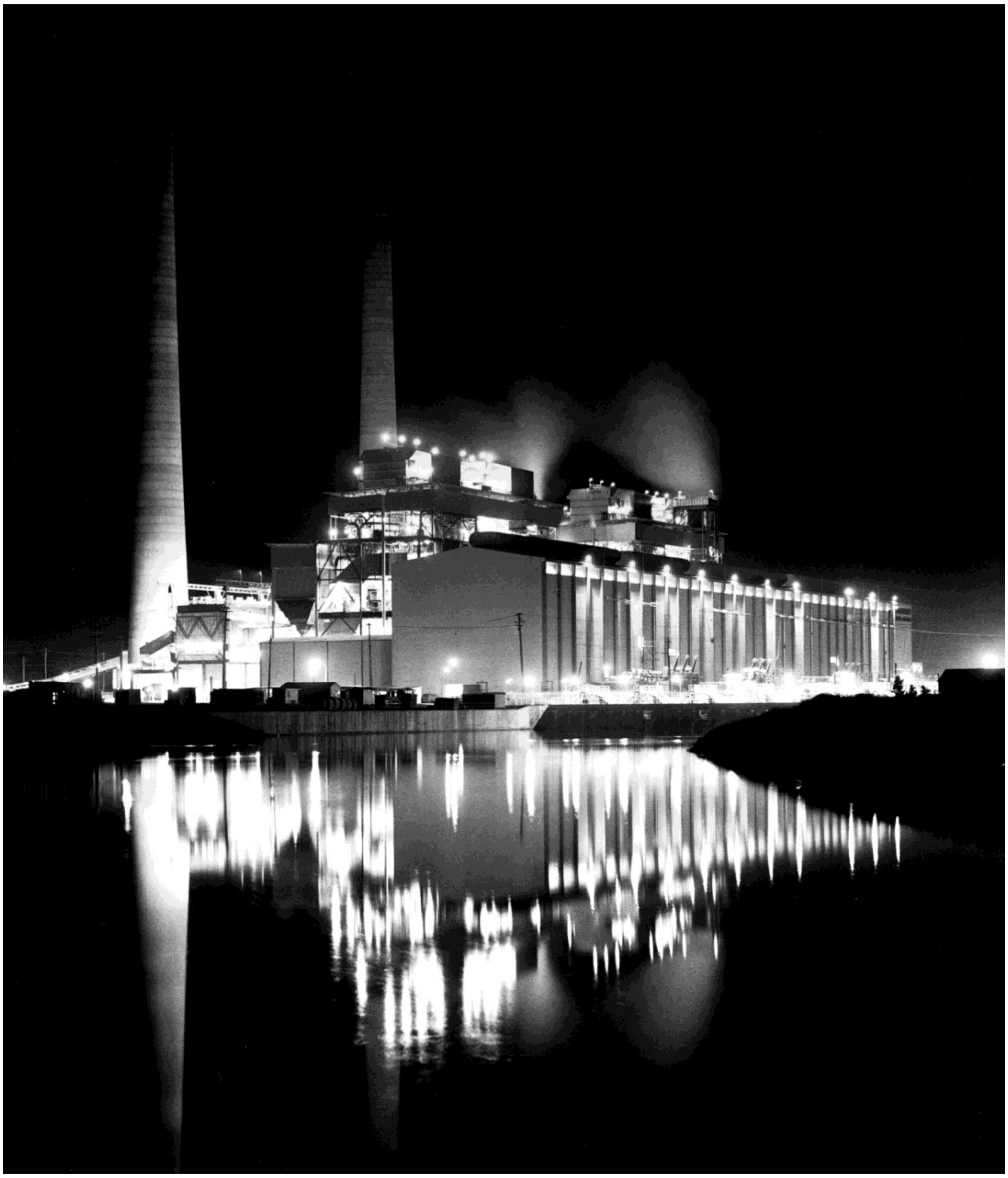
MUNMORAH POWER STATION

TUGGERAH LAKES, N.S.W



Nomination for Award of Historic Engineering Marker

Prepared for

Engineering Heritage Australia (Newcastle)

Cover photograph: Munmorah Power Station at Night, 3 February 1970 - (ECNSW 09286)

Preface

Frank Brady, a former Vice-Chairman, Chairman and General Manager of the Electricity Commission of New South Wales (ECNSW), suggested that heritage is generally linked to physical objects.[1] In the legal system, for example, heritage can be seen in the profession's treasures or the headwear and gowns that judges and barristers wear. Likewise, legal heritage also encompasses the Rule of Law, the Australian Constitution, former prominent legal luminaries and the jury system. In the same way, the heritage of the power generation industry extends beyond gleaming vertical reciprocating steam engines, marble-floored control rooms, or large complex thermal power stations. The industry's social impact; a specific piece of infrastructure's bearing on its local environment; the rarity of a piece of infrastructure; or the degree to which it represents the industry or a particular era, are also encompassed by the term heritage.

The New South Wales (NSW) electricity system embodies the fundamental infrastructure of the State's modern society. This statewide machine of power stations, transmission and distribution networks reaches into nearly every home, office, shop, factory, and institution. It is the largest single machine in the State. It encompasses many power stations using a range of fuels and technologies. Thousands of kilometers of transmission lines and distribution networks transport electricity to consumers. It is also the State's most expensive infrastructure investment albeit over many decades.

Munmorah was the second (after Vales Point) major power station designed and commissioned by the Electricity Commission of New South Wales following its formation in May 1950. The first of its four generating units was commissioned in February 1967. At that time its 350 MW units were the largest on the NSW network. From 1969, Munmorah was the Electricity Commission's largest power station until Liddell's third 500 MW unit was commissioned in 1972.

Munmorah, as with each of the Electricity Commission's new power stations incorporated many new and innovative technologies - many being firsts for the organisation, the state and nationally. However, the all-electric analog combustion and generation control system set the station apart from its Electricity Commission, and national predecessors. This control concept was the forerunner of control systems in future NSW and Australian power stations.

This document details the information required by Engineers Australia *Guide to Engineering Heritage Recognition Program (2012).*

The accompanying document, *'The New South Wales Electricity System'* outlines the history of the State's high-voltage electricity system as operated by the ECNSW between 1950 and 2003. This document expands on the engineering heritage of a single physical object, by presenting background information on the NSW bulk electricity generation and transmission industry. This information may also be used as background information to subsequent applications for other power stations or infrastructure operated by these organisations. Equally, this information could form the basis for engineering heritage recognition of the NSW electricity system itself.

[1] Alan Deans, "Frank Brady", *Australian Business*, 1 April 1982.

Acknowledgements

The author wish to acknowledge the following people and organisations for their invaluable help in the research for this application.

Rod Caldwell for the initial idea to apply for an engineering heritage award for the station.

Many former colleagues of the Electricity Commission of New South Wales, Pacific Power, and Delta Electricity, who gave of their time, expertise in the form of one-on-one interviews and the loan or gift of photographs, documents or memorabilia.

Heritage consultants C and MJ Doring and in particular their 1992 publication *Vales Point "A" Power station Heritage Study 1959 to 1989*.

'Munmorah Power Station' in Mark Fetscher's self-published 2001 *The Power Makers*.

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Generator Property Management Pty. Limited, the current managers of Munmorah site, for their assistance in accessing Munmorah's documentation archive.

A significant portion of this application, and the accompanying *The New South Wales Electricity System*, was sourced from the author's 2015 Ph.D. thesis "The Electricity Commission of New South Wales and its place in the rise of centralised coordination of bulk electricity generation and transmission 1888-2003,"

Finally, all errors and omissions of fact are the author's.

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April 2017

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Table of Figures

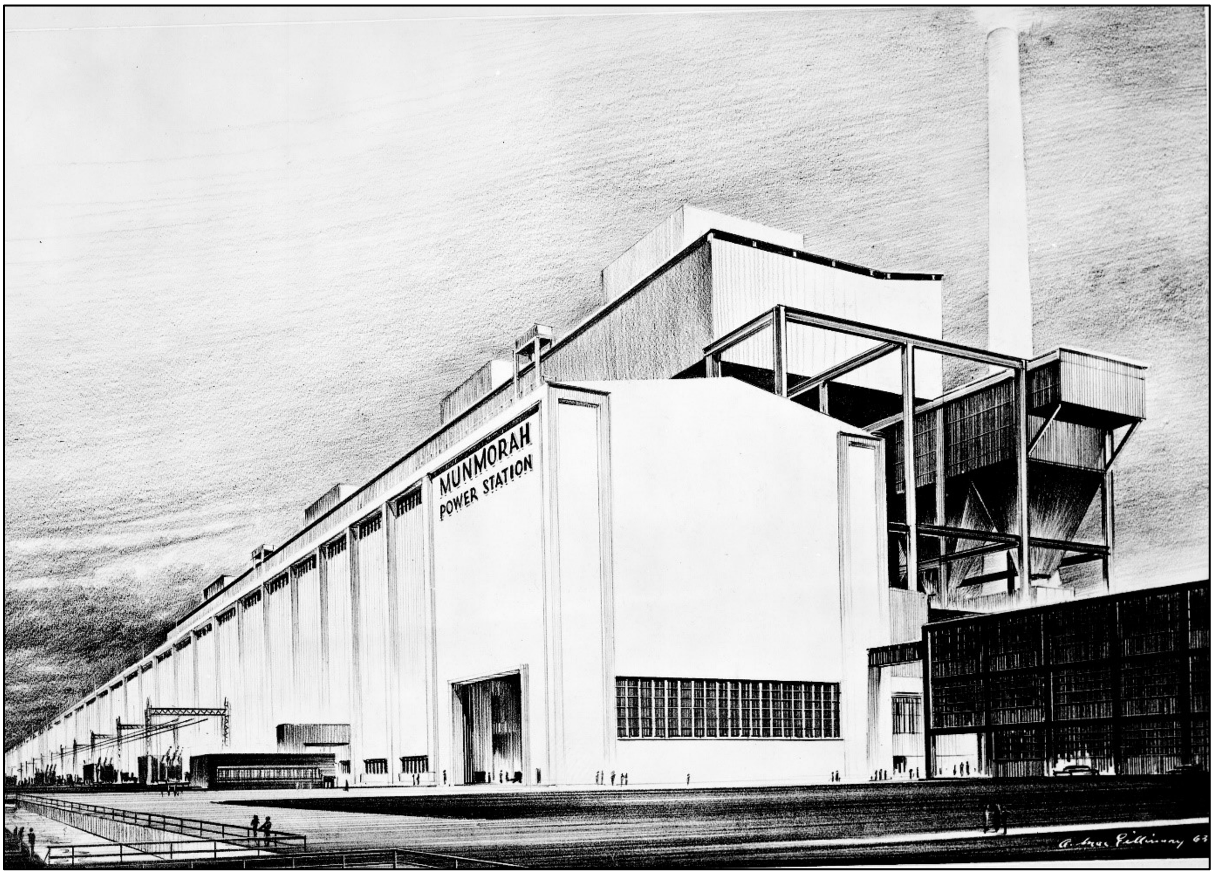


Figure 1 Artist's impression of Munmorah – 1966 (ECNSW 04425)

Munmorah Power Station Heritage Assessment

Munmorah was approved for construction in February 1961. Its first 350 Megawatt (MW) generating unit was synchronised in February 1967 and its last in October 1969. For three years, at 1400 MW, it was the Electricity Commission's premier power station. Liddell assumed that role in December 1972 with the commissioning of its third 500 MW generating unit. Munmorah's last operating generating unit (#3) was decommissioned in August 2110 after forty-one years of service to the people of New South Wales. In 2017, Munmorah is being demolished.

Basic Data
Item Name:

Munmorah Power Station

Other/Former Names:

N/A

Location (grid reference if possible):

33^{0}12'41"S 151^{0}32'31.78"E

Munmorah Power Station is situated near Doyalson, Lake Macquarie, New South Wales

Address:

Station Road, Colongra, NSW, 2262

Suburb/Nearest Town:
Halekulani, Doyalson and San Remo NSW, 2262

State:
New South Wales

Local Govt. Area:
Central Coast

Owner:
Former owners of Munmorah Power Station are:
1967 - 1996 - Electricity Commission of New South Wales / Pacific Power
1996 - October 2016 - Delta Electricity
November 2016 – present - Generator Property Management Pty Ltd

Current Use:
Munmorah Power Station has been decommissioned and is currently being demolished (November 2016.)

Former Use:
Munmorah Power Station, in its forty-three year production life, made a considerable contribution to meeting the demand for electricity in NSW, and later the south-eastern Australian electricity grid. Munmorah's first generating unit was commissioned in February 1967, and the final electricity was produced in August 2010.

Timeline:

Station construction authorised	February 1961
Civil works commenced	December 1961
Turbine House construction commenced	June 1963
Unit 1 Boiler construction commenced	December 1963
CW canal opened to Lakes	February 1966
Unit 1 synchronised	February 1967
Unit 2 synchronised	March 1968
Unit 3 synchronised	March 1969
Unit 4 synchronised	October 1969
Units 1 & 2 decommissioned	July and August 1990 respectively

Units 1 & 2 placed in storage	1991
Unit 3 placed on stand-by role	1998
Unit 4 placed in storage	1998
Unit 4 returned to service for period of time	February 2000
Unit 4 last generation	March 2009
Unit 3 last production	August 2010

Designer:
Electricity Commission of New South Wales

Major Equipment:

Boilers	International Combustion Australia Ltd.
Turbo-generators	The English Electric Company of Australia Pty. Ltd.

Physical Description:
Munmorah produced electricity with bituminous coal as the primary fuel source. The basic process used at Munmorah was identical to all Electricity Commission / Pacific Power stations.[2] Admittedly, there were differences in the type or manufacturer of various item of plant and equipment, but the basic process did not differ.

Station Layout
As with the nearby Vales Point Power Station, Munmorah was orientated with its long axis running south-west to north-east. Aesthetically, the visible aspect of Munmorah is similar to the earlier Vales Point and later Liddell, Eraring, Bayswater and Mt Piper power stations.

Munmorah’s turbine hall is 270 metres long and thirty-five metres wide.

Two boiler structures each containing two 62-metre high boilers were to the immediate south-east of the turbine hall with two 155-metre tall chimney stacks further to the south east.

Not including the ash disposal and associated coalmines the Munmorah site covered approximately 570 hectares.

Coal Supply
Vales Point and Munmorah were constructed because of the Electricity Commission of New South Wales's ongoing policy of locating major thermal power stations on the coalfields, at the source of fuel. This meant considerably reduced fuel costs when compared with their load

[2] *Munmorah Power Station - Pamphlet*, (Pacific Power, 1992-1996). 21. *Electricity Commission of New South Wales / Pacific Power Annual Reports 1953 - 2000*: 1953 - 2001.

based predecessors. The Electricity Commission was thus able to generate electricity at declining productions into the late 1960s and early 1970s.

Coal for Munmorah was initially supplied from two adjacent underground coal mines, Newvale #2 operated by Newstan Colliery Pty Ltd and Munmorah State Mine. Coal was delivered either directly into the station bunkers for immediate use, or to the coal storage area which held a total reserve of 762,035 tonnes, including 30,480 tonnes in Live Storage.

In the early 1970s a 400 tonne per hour conveyor system linking Munmorah and Vales Point enabled the two-way transfer of coal between the two stations. With the commissioning of the Vales Point rail unloading loop and conveyor transfer system adjacent to the main northern railway line at Wyee in 1981 coal from distant coal mines became available.

Cooling Water

The station's cooling water was taken from Hammond Canal that connects Lake Munmorah and Lake Budgewoi. The inlet canal section from Lake Munmorah is 1874 metres long, thirty-four metres wide at the surface and five metres deep. The outlet canal section to Lake Budgewoi is 1860 metres long, including a 426-metre long concrete tunnel.

Cooling water was required to condense spent steam from the turbines back into water for reuse in the boilers. This water passed through each unit’s condenser at a rate of about 16,000 litres / second when the unit was at full load. After being used in the power station, the water was discharged via an outlet canal into Lake Budgewoi.

Fresh water for boiler make-up purposes and general station use was supplied from Hunter Water and stored in two 2. 954 ML main storage tanks. Up to 318,226 litres per day was prepared in the station’s Demineralising Plant for use as boiler make-up water.

Boiler

Munmorah’s boilers were designed by International Combustion UK and manufactured by International Combustions Australia Limited. The units were unconventional in that they were mid-supported with downwards firing.[3] The heating surfaces were arranged upside down to a conventional unit. The design supposedly reduced the cost of structural supporting steel. It is one of a kind design, however unlikely to be used is later configurations.

The maximum continuous evaporation was 309 kg/sec at a pressure of 16,500 kPa.

A multi-stage superheater with three horizontal self-draining stages was located in the front pass. The furnace roof was formed by the first stage elements. The second stage was also located at the top of the furnace above the burner level while the final stages were grouped with the reheater elements at the bottom of the furnace.

Final steam temperature control was achieved by spray de-superheaters in the superheater headers (between the 5th and 6th stage) and by tilting burners. Final superheater temperature was 565ºC.

[3] Burns and Roes Worley Pty Ltd., *Feasibility Study for Capacity Upgrad of Munmorah 3 & 4 Units* (Sydney2005). 35.

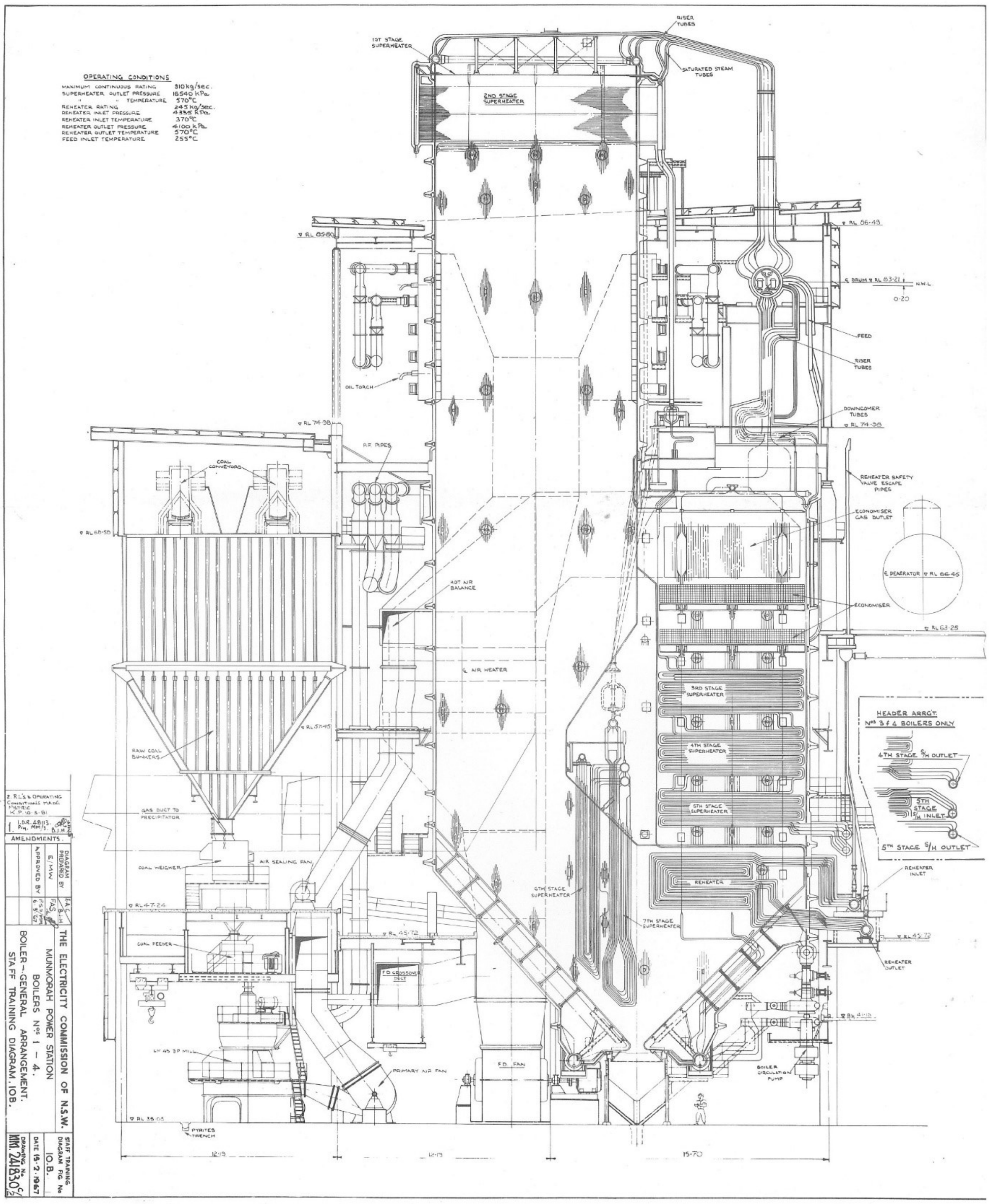


Figure 2 Cross section of Munmorah Boiler (Courtesy Jim Nagle)

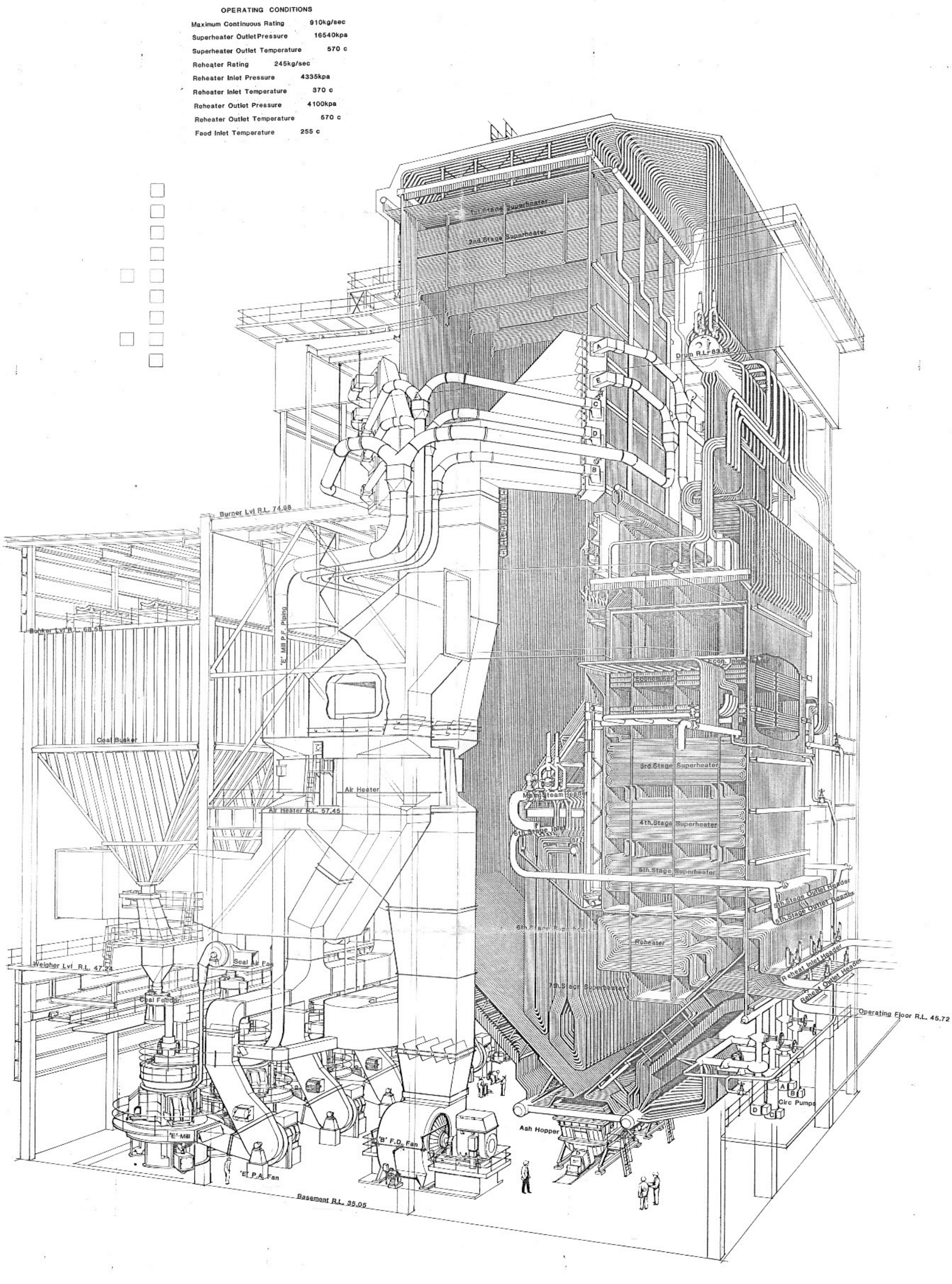


Figure 3 3D view of Munmorah boiler (coutrtey Jim Nagle)

After passing through the High Pressure turbine, steam was returned to the boiler and entered the Reheater at 371ºC and was returned to the Intermediate Pressure turbine at 540ºC.

The Boiler Circulation Pumps were of the "canned" type in which the electric motor was within the pump casing and immersed in boiler water at full boiler pressure. The Station's 1969 *Opening Souvenir Book* noted, "this type of pump was developed originally for nuclear power stations and overcomes sealing difficulties encountered on conventional pumps where the driving spindle enters the pump body. Four circulation pumps were provided for each boiler."[4]

The bolier's combustion chamber was 56 metres high, eleven metres deep and 14 metres wide.

Pulverised fuel entered the boiler's combustion chamber via corner-sited fuel burners. These can be tilted up or down to control the combustion process.

Pulverising Fuel (PF) Mills

Before being admitted to the combustion chamber (furnance) coal was crushed to the consistency of talcum powder in grinding mills. Each pulverising mill consumed approximately 37.5 tonnes per hour.

The pulverising plant consisted of five "Lopulco" IM 45/3P, three roller, mills with associated primary and sealing-air fans and table type coal feeders. The mills were of the pressure type having a primary air fan located ahead of each mill to provide air for transporting pulverised coal from the mill to the furnace. Of the five mills provided on each boiler, four mills were capable of maintaining full boiler load. The fifth mill was available as a standby to permit replacement of worn grinding parts without reduction in load on the boiler.

Fans

Induced Draft: each unit had two.

Forced draft: each unit had two.

Primary Air: each PF mill had one.

Boiler Feed Pumps

Each boiler had two 50% duty electrically driven feed pumps, and one 100% duty bled steam turbine driven feed pump.

Ash and Dust Plant

The Ash and Dust Plant was designed to remove a maximum of 100 tonnes of ash per hour, and a maximum of 145 tonnes of dust per hour.[5]

Electrostatic Precipitators were initially installed on all units. The Station's 1969 *Opening Souvenir Book* noted, "experience at Commission's power stations has shown that larger electrostatic precipitators than those usually found necessary in Britain and the United States are needed to collect the dust from the flue gases produced when burning N.S.W. coals. The design information used in determining the precipitator size was based on earlier pilot plant testing and experience gained with electrostatic precipitators at the Commission's other power stations. The dust collecting plant at Munmorah consists solely of electrostatic precipitators operating at about 40,000 volts direct current. The precipitators collect more than 99 per cent of the dust in the flue gases and the stack emission was well within the Clean Air Act requirements."[6]

[4] *Munmorah Power Station - Souvenir Opening Book*, EC.061 (Sydney: Electricity Commission of New South Wales, 1969). 22.
[5] "Munmorah Power Station - Souvenir Opening Book," 27.
[6] "Munmorah Power Station - Souvenir Opening Book," 26.

Fabric Filter Dust Collection plant was installed on Units 3 and 4 as part of a major upgrade in the late 1980s / early 1990s.

Turbine - Generator[7]

Each of the four English Electric turbines were four-cylinder, tandem impulse reaction type, using reheat and with high pressure, intermediate pressure and twin flow low-pressure cylinders arranged in-line. Operating speed in 3,000 rpm. Each turbo-generator was approximately forty-one metres long and weighs 1,200 tonnes.

The H.P cylinder was of partial double casing construction. Steam at 16,100 kPa and 565° C entered via the centre of the outer casing into the inner casing and expanded towards the governor end of the turbine through five stages in the inner casing. It then flowed back over the inner casing and exhausted at the alternator end through a further three stages. Steam was exhausted to the Reheater at 4,100 kPa and 370° C (full load).

The I.P steam inlet at 3670 kPa and 540° C was adjacent to the H.P exhaust with expansion through the I.P. cylinder's seven stages towards the alternator. The reverse thrust exerted in the first stages of the H.P. cylinder tends to be balanced by the combined thrust of the final stages of the H.P. cylinder and the I.P. cylinder thrusts. The residual thrust was taken by the thrust bearing located between the H.P and I.P cylinders.

Steam left the I.P cylinder exhaust via two 105 cm bore pipes arranged along the sides of the turbine, and entered the L.P inner casings at each side of each L.P cylinder via 80 cm bore pipes. These transfer pipes incorporated corrugated steel bellows for flexible expansion.

Each L.P cylinder consisted of two impulse stages and three reaction stages. The steam divided into two flows in each L.P cylinder and the two cylinders exhausted into two separate condensers.

The L.P cylinders were self-balancing on thrust.

The H.P and I.P blades were mounted on solid forged steel rotors, while the L.P rotor discs carrying the moving blading were shrunk and keyed on,. The two L.P rotors were physically identical and were interchangeable. All sections of the shaft were solidly coupled.

Bled steam was extracted from a number of points on the turbine steam path and used in the regenerative feed heating cycle.

Continuous Maximum Rating as installed was 350 MW. However, each unit was de-rated to 300 MW in 1984. The main reasons for this included:[8]

1. Not competitive in a system which had excess generation.
2. Rapid consumption of creep life in the turbine and the boiler.
3. Feed Heater problems.
4. Boiler erosion.
5. Mill capacity.
6. Hydrogen embrittlement.
7. Condenser Tube leaks / cooling limitations.

Operating speed: 3,000 rpm

[7] *Turbine Generator General Description*, ed. Geoff Byrant, Munmorah APPO School Manual (Munmorah Power Station: Delta Electricity, 2004).
[8] ———, "Feasibility Study for Capacity Upgrad of Munmorah 3 & 4 Units," 17-18.

Voltage 17.5 kV
Current 12, 840 amps
Generator cooling:[9]

Stator: The windings of the generator are hollow and are directly cooled by distilled water circulating through them. The water was taken to and from the windings by insulating hoses and itself was cooled in external heat exchangers.

Rotor: The generator housing was filled with hydrogen gas at a pressure of 3 bar. Fans on the generator rotor circulate hydrogen through ducts in the rotor and in the rotor windings. The heat produced by the losses in these parts warms the hydrogen which was cooled by flowing past nests of water-cooled tubes mounted within the generator casing.

Condensers

The twin Condensers on each unit had a cooling water flow of 772,835 litres per minute. Two 0.894 MW Circulating Water Pumps per unit produce 408,011litres per minute

Chemical Control

Munmorah was the first ECNSW station to use a Feedwater Polishing Plant. These were used during unit start-up to remove excess contaminates from the feedwater system

Electrical

330 kV switch yard

Provided for the connection of four 330 kV transmission lines, four generators and two station transformers. The '$1^1/_2$' circuit breaker scheme was adopted - three circuit breakers being used for each pair of main circuits consisting of a generator and a transmission line. The 330 kV circuit breaker were of the air blast type

Generator and main transformers

Three single phase 17.5/190 kV water-cooled on-load tap changing transformers forma 17.5 / 330 kV 400 MVA 3 phase bank for each generator.

Auxiliary supply

Station transformers - two 80 MVA 330.33 Kv on-load tap changing supplying 33 kV to the mines sub-stations and to 34 MVA 33/11/3.3 kV station auxiliary transformers.

Unit Auxiliary transformers - four 25 MVA 17.5 / 11 kV

Control

Munmorah was the EC's first power station to utilise an all-electric rather than pneumatic operated boiler-turbine control system.

Two plant control rooms between the turbine house and boilers are each equipped for the remote starting and control of two boilers, the remote control of two turbines, and the remote control of coal supplies to boilers and the supervision of ash and dust plant. The remote control of the switchyard was carried out from No. 1 plant control room. The control system for each boiler-turbine unit was of the all-electric type using electrical transmission of signals from plant and electric actuators which moved valves, dampers and regulators to adjust flows, temperatures and pressures on the plant in order to maintain the required conditions. The control system worked on the direct energy balance principle in which a variation in the generated output was balanced by a corresponding variation in the fuel and combustion air

[9] "Munmorah Power Station - Souvenir Opening Book," 30.

input to the boiler. The system also controled a number of auxiliary automatic controls regulating other quantities within the boiler turbine plant such as steam temperatures and pressures, feedwater supply and water level in feedwater heaters. A detailed description of the control system can be found at 'Creative or Technical Achievement.'

Computer

Two digital computer systems were provided, one for each pair boiler-turbine units, for plant monitoring, data logging and thermal performance evaluation duties. Each computer system constantly scaned 2,400 inputs from the plant test points. Each point was scanned every two minutes and some scanned as frequently as every six seconds. If any point exceeded permissible operating limits, an alarm was raised. Further, any of the plant measurements scanned by the computer could be displayed to the operator either on digital indicators, on chart recorders or in the form of typewritten statements. These statements were printed out at rates of up to 20 lines per second. Trends in plant behaviour could thus be conveniently observed. The computer loged selected plant data and all plant data were stored in the computer's memory at regular time intervals. The analysis of plant operation, both in the short term, e.g., after a disturbance, and in the long term, viz., over periods of weeks and months, could be readily carried out. The computer also measured quantities, made calculations and presented vital information such as the actual figures of boiler efficiency, the turbine heat rate in relation to the target figures and a number of other important values pinpointing the cause of any fall in performance; the apporpriate corrective action can thus be taken without any delay.

Transmission

The output of each of Munmorah's generators was fed into a 330kV switchyard via step-up transformers. Here electricity was fed into three 330kV transmission lines. Two were connected to Sydney and a third to nearby Vales Point Power Station.

Physical Condition:

The power station is being demolished

Modifications and Dates:

Plant Life Extension 1988 - 1992

Munmorah's Plant Life Extension regime allowed the Station to continue operation through to 2010 and be available until 2012 – i.e. 45 years of operation, or greater than 50 years since design.

In the 1960's, the design life for major power station components was specified as 25 years. This was the framework for Vales Point 'A', Munmorah, Liddell and possibley Vales Point 'B'. There was a targeted Plant Life Extension philosophy applied to Munmorah and Liddell. In 1986 John Marcheff and Bob Porter were sent on a fact-finding trip to the U.K. to talk to the Central Electricity Generating Board (CEGB), English Electric and Parsons on measures required to extend the life of the generating assets (and turbo-generators in particular) out to 50 years.

Between 1988 and 1992, a structured programme of Plant Life Extension on the Munmorah Units was implemented. This included an Environmental Upgrade, and other similar elements.

The Leeds and Northrup Direct Energy Balance control system was replaced by the Bailey Network 90 system. While both control systems were electrical / electronic rather than pneumatic, the main difference was that the later system was digital rather than analog.

The capital budget over those years was more than $200 million.

The importance of the overall plant extension project was somewhat diluted by the dramatic generation over-supply scenario that prevailed within Pacific Power (and elsewhere throughout south-east Australia) in the mid-1980s and early1990s. Over-supply resulted in the 660 MW units at Mount Piper being mothballed for two or three years before being commissioned in 1992 and 1993. By this time, Munmorah Units 1 and 2 had been placed in long-term storage and saw very little, if any generation thereafter.

Assessment of Significance

Historical Significance:

Munmorah's heritage significance derives from the first use in NSW and Australian power stations of an all-electric, rather than pneumatic, operated, boiler-turbine control system. Equally important, Munmorah was the first to use computers in monitoring the production process.

The plant is significant because it was an example of large base-load thermal power generation plant. With the commissioning of the first of the 350 MW units at Munmorah, in February 1967, it became the largest on the NSW network until the first 500 MW unit at Liddell (#2) came online in May 1971. With the commissioning of Munmorah #3, the station became the largest power station in NSW exceeding Vales Point A's 875 MW. Munmorah retained the EC's premier station until Liddell's third 500 MW unit was synchronised in December 1972.

Creative or Technical Achievement:

All Electric Control System

Before describing the combustion and generation control system (direct energy balance control system (DEB)) installed at Munmorah, a review is warranted of the then conventional method of controlling the electricity generation processes. This will contribute to a greater appreciation of why Munmorah's control system is so significant in the history of NSW power stations.

In earlier power stations, the various processes that contributed to the final output of electrical energy were conceived as separate entities – boiler plant; turbine plant; coal handling, and ash and dust.[10] The boiler operator's role was to supply steam to the station's common steam receiving system. His plant used coal supplied by the coal plant operator. The turbine operator's role was to ensure that the turbine operated at constant speed using steam taken from the station's common steam system. The electrical control room operator was concerned with generation output, voltage control and the distribution of electrical energy to local networks. Over many decades, individual control centres became more complex as improved instrumentation, alarm systems and plant controls were installed. Wangi A was one, if not the

[10] C Ayers, Campbell, C.L.,, "Automation in the Power Station," *The Australasian Engineer* September 1965: 83.

last ECNSW power station to have separate individual control centres.[11] Wangi B incorporated a Plant Control Room were the boiler and turbine controls were in one location. The electrical output controls for both A and B sections were in a single Electrical Control Room. Vales Point A continued this centralising trend with all controls for Units 1 and 2 located in #1 Plant Control Room, and those for Units 3 and 4 in #2 Plant Control Room. Munmorah and later power station continued this trend.

Vales Point 1 to 4, despite their many innovations, including the first use of reheated steam in Australia, represented the end of an era, at least in the philosophy of combustion and generation control. These units and previous NSW power station's incorporated analog pneumatic systems for instrumentation and control of critical processes. In its simplest form, compressed air was both the control medium and the power medium. Critical parameters, such as actual steam pressure at the turbine stop valves, steam flow, fuel flow and air flow were derived through pneumatic instrumentation. Fan dampers and other process actuators and regulators were pneumatic controlled and driven.

As illustrated in Figure 1, the crux of Vales Point A's combustion control involved changes in electrical output (MW) resulting in changes in steam pressure and steam flow.

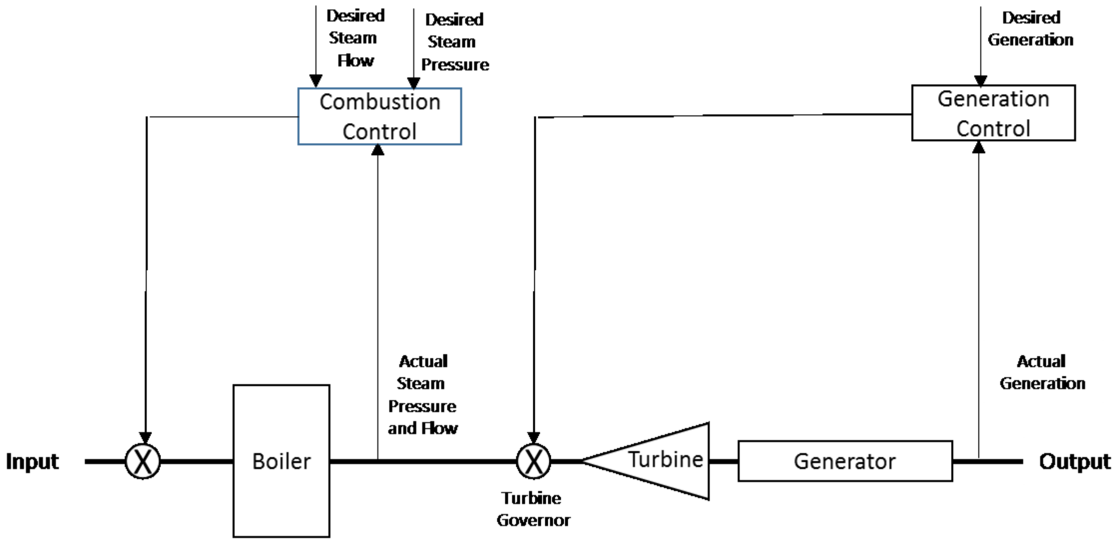


Figure 4 Pre Munmorah Combustion and Generation Control[12]

Changes in steam pressure resulted in changes in fuel flow to the boiler, while changes in steam flow resulted in changes in airflow. An inherent, if not the primary, characteristic of this type of control system are process lags or time delays. For example, an increase in MW output resulted in a subsequent fall in steam pressure at the turbine stop valves. This reduction in turn has to be detected by pneumatic instrumentation and a pneumatic signal generated that became an input in the Combustion Control system. In many respects this was a consequential or serial control system. A change in a parameter had to be detected before a control signal was generated to instruct the relevant process component to respond.

[11] C. and M.J. Doring, *Wangi Power Station Heritage Study* (C. & M.J. Doring Pty., 1990). 455-69.
[12] The description of the Direct Energy Balance Control System relies heavily on - K.F. Walker, "Analog Controls and digital Data Processing Applied to Munmorah Power Station," *The Australasian Engineer*, no. September 1965: 87-93.

As boilers increased in size to meet demands for higher steam pressures and temperatures their pneumatic control systems were difficult to adapt to improved control strategies. Equally important, in the early 1960s, electrical / electronic automatic load frequency control systems had been installed in the systems of the State Electricity Commission of Victoria and Snowy Mountains Hydro. Operational experience showed that the power station pneumatic control systems were not sufficiently responsive or reliable to competently perform this automatic function. Control system designers were also mindful that boiler input controls and generator output controls inherently affect each other and in certain circumstances could produce cycling of steam pressure and generator output.

To resolve control system responsiveness inherent in process lag and cycling issues, Leeds and Northrup introduced their Direct Energy Balance control concept (DEB) to provide coordination between adjustments to the turbine governor and the combustion control system. Munmorah was the first Electricity Commission (and Australian) power station to utilise this new all-electric concept.

This system had two primary components. The first, incorporated electrical, rather than pneumatic, instrumentation to determine process parameters, and the transmission of control signals to the plant and electric actuators used to move valves, dampers and regulators to adjust flows, temperatures and pressures.

The second component, the DEB system itself, essentially operated on the principle that irrespective of whether desired generation changes are initiated locally or remotely, the boiler and turbine generator were adjusted simultaneously to obtain optimum performance. Frequency bias, limits, runback and rate of change functions prevent desired generation changes from exceeding the capabilities of the boiler, turbine and their auxiliaries. The direct energy balance concept is illustrated in Figure 2. A desired generation signal is applied to the boiler-turbine-governor component of the DEB control signal which produces a required output signal that is within the capabilities of the boiler, turbine and auxiliaries. The required output signal cannot be varied at a rate which exceeds a pre-set rate of change value except under emergency conditions when runback actions will take place at an emergency rate of change. Pre-set limits will also prevent the required output signal exceeding desired values.

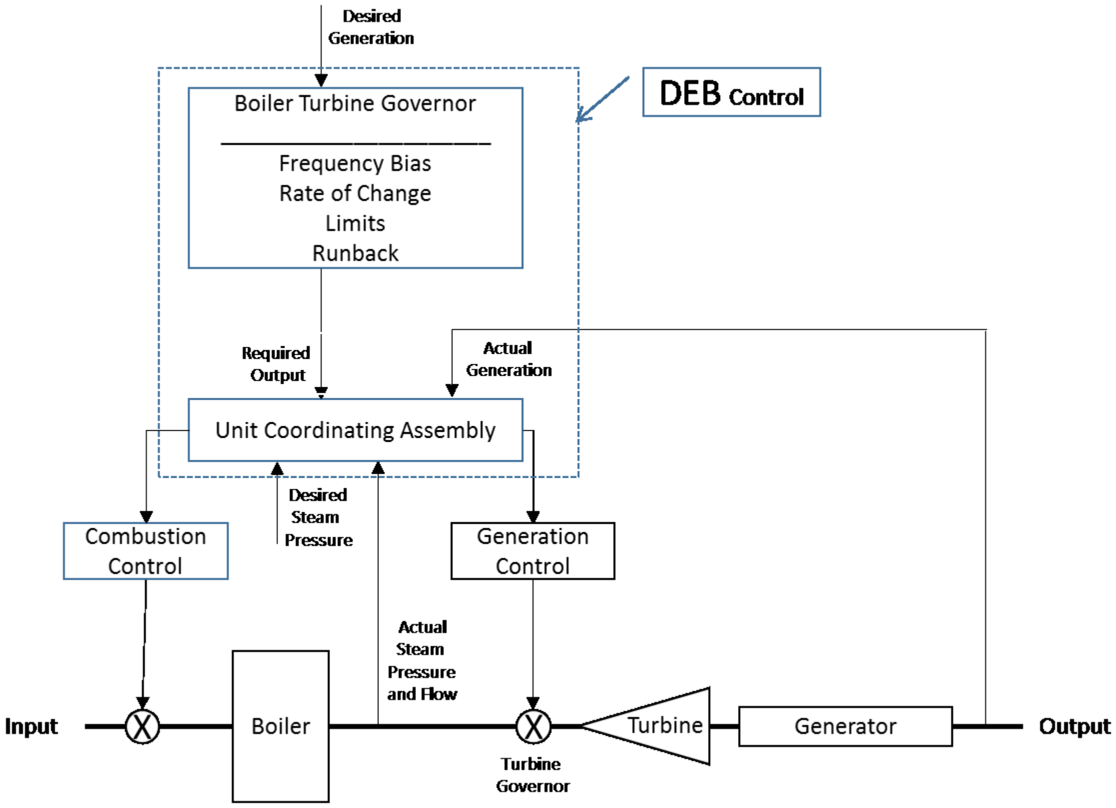


Figure 5 Direct Energy Balance Control System

The required output signal and an actual generation signal are applied to the Unit Coordinating component of the DEB control system, as are desired steam pressure and actual steam pressure signals. The Unit Coordinating component (Figure 3) integrates the control action of the Combustion control and governor control systems.

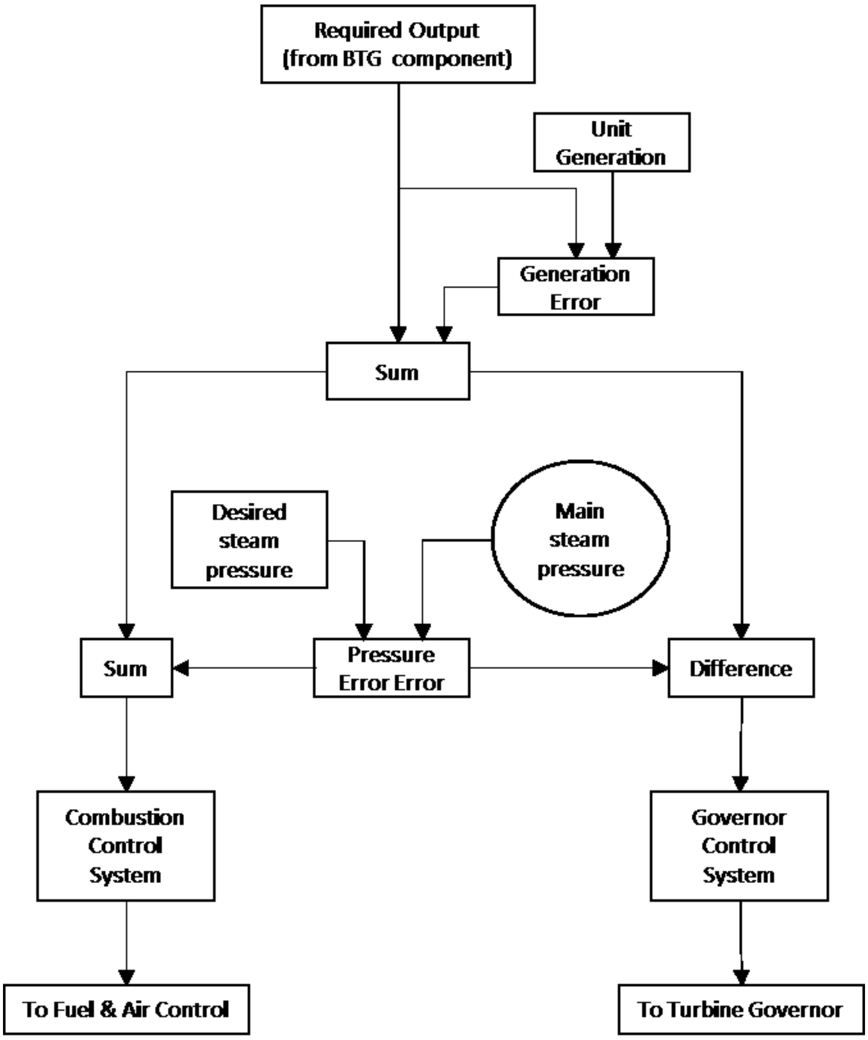


Figure 6 Unit Coordinating Assembly

Under normal conditions the required output from the boiler-turbine governor control system will provide a control set point for the combustion control system and the governor control system. Required output is also compared with actual generation and should a difference exist then a generation initiated correction signal will be applied to both the combustion and governor control systems. Steam pressure is compared with a manually adjustable set point value and again if a difference exists then a pressure initiated correction signal will be applied in parallel to the combustion and governor control systems.

Reference to Figure 6 indicates that the pressure initiated correction signal is added to the generation initiated correction signal being applied to the combustion control system but is subtracted from the same signal being applied to the governor control system. This arrangement merely reflects the opposite effects which adjustments to fuel input and governor action have on steam pressure. Whereas an increase in fuel input to the boiler increases steam pressure an increase in governor setting decreases steam pressure and the reverse is true in each case.

Apart from the DEB automatic control system described above, the Munmorah Operator had three other modes of control available. These are Manual, Boiler Follow (Boiler Pressure Control) and Turbine Follow (Base Load).

Computer

Complementing the direct energy balance control system, Munmorah incorporated two digital computer systems that provided plant monitoring, data logging and thermal performance evaluation duties. Each pair of generating units shared a digital computer. Each computer system scanned 2,400 inputs from the plant test points. Each point was scanned at least every one minute with many of the most important as frequently as every six seconds. If any of the points exceeded permissible operating limits an alarm was raised. Further, any plant measurement scanned by the computer can be displayed to the operator either on digital indicators, chart recorders or in the form of strip printer statements. These statements can be printed out at rates of up to 20 lines per second. The trends in the plant behaviour can thus be conveniently observed. Selected plant data are logged by the computer and all plant data are stored in the computer memory at regular time intervals. The analysis of plant operation, both in the short term, e.g., after a disturbance, and in the long term, viz., over periods of weeks and months, can thus be readily carried out. The computer also measures quantities, makes performance calculations every 2 minutes and presents to the operator hourly, vital information such as the actual figures of boiler efficiency, the turbine heat rate in relation to the target figures and a number of other important values pinpointing the cause of any fall in performance; the corrective action can thus be taken without any delay. All computer variables were are looged hourly on magnetic tape for storage and analysis.

Figure 7 illustrates an article from the Electricity Commission's Staff Newsletter 'Network' describing the computer syste. Ground breaking as the introduction of computers to the power generation process, the editor of 'Network' chose to showcase it rather than the technical breakthrough of the Direct Energy Balance Control System.

Over and above computer and the new control equipment, Munmorah was used, particularly in its latter years, as a test-facility for new and innovative electricity generation technologies. Foremost in this field were the Plasma Ignition System and the Carbon Capture Pilot Plant.

COMPUTER FOR MUNMORAH

The Computer System for Munmorah can be best described, perhaps, as a "watchdog"—sounding the alarm if things go wrong. It constitutes an extensive scanning and monitoring system of information throughout the plant which is drawn to the Operator's attention only when necessary. It provides a continuous scan of some 760 points associated with each unit which can be called upon by the Operator for information whenever he so desires and his attention will be directed specifically to a particular point if it should indicate trouble. Further, the equipment assists the Operator in a variety of other ways to achieve efficient operation of the plant.

By J. B. KIRKWOOD

In general, the operation of the generating units at Munmorah will be similar to Vales Point — remote control and supervision from two Plant Control Rooms, each housing the necessary instruments and controls for two generating units.

The new feature of Munmorah, however, will be this digital "watchdog"—a high-speed digital computer which will provide a tremendous extension of the facilities for scanning selected points throughout the station to ensure that everything is functioning correctly. This has permitted a reduction to be made in the number of conventional instruments installed; a simplification which is one of the objectives of the installation.

The computer system will serve as an information centre which will give the operator precise information about all aspects of the plant on demand. It automatically checks information throughout the plant and does not require any attention from the operator. However, it will sound an alarm and draw his attention to temperatures and/or pressures which have gone beyond prescribed limits or are changing too rapidly, or to other factors which might indicate trouble.

The operator may, of course, call for any information about the plant condition which he may require and the computer will immediately display this information for him at the operating desk.

It will also provide—

- A routine log of information and relieve the operator of this routine task.
- Automatic assessment of the thermal performance of the generating units pointing out the area and extent of any deviation from the desired performance.

It is important to remember that the computer system is to assist plant operators by automatically checking information throughout the plant and when necessary providing them with additional information. It will not relieve them of their prime task of control.

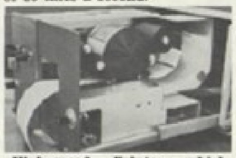
● Computer System Equipment

The system now being installed at Munmorah is referred to as an LN.4200 system and is being supplied by Leeds and Northrup Co., of Philadelphia, USA. It consists of a central computer together with peripheral equipment arranged as follows:—

1. Two computer communication consoles (one for each unit operator's use). These contain various push-buttons and selector switches by means of which the operator can demand and specify the information that he requires from the computer or carry out limited changes in the computer instructions.

2. One computer communication console for engineering staff. The provision of this additional control console ensures that the plant operator will not be distracted from his duties by the engineering staff wanting to use the computer.

3. Three Alarm Printers (One adjacent to each of the consoles mentioned in 1 and 2 above). These will print detailed alarm messages and other information on narrow paper tape at the rate of 20 lines a second.



High-speed Printer which gives details of trouble locations.

4. Three logging typewriters (one for each unit and one on-line stand-by). These typewriters will print a set of selected data on log sheets at regular intervals for record purposes.

5. Three special logging typewriters (one for each operator and one for the engineering staff) these machines will print various data when requested to do so.

6. Eight Trend Recorders (four for each unit). These recorders will display any of the computer measurements in the form of a recorder trace when required.

7. Two Digital Displays (one for each unit). These are the indicators displaying any measurement from plant in digital form (set of numerals).

8. Two sets of Trouble Location Annunciators (one for each unit). These are miniature annunciators associated with the computer alarm system and the general area of any trouble.

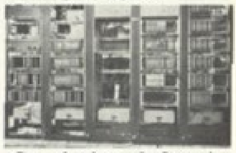
9. Magnetic Tape Attachment (known as Magpak). Stores selected data for reference and subsequent processing and analysis.

10. Graph Plotter. An automatic graphing device which will plot the relationship between any of the factors recorded on the magpak unit. The primary purpose of this equipment is for investigation work.

Graph Plotter on left and Magnetic Tape unit on right.

11. Two Test Recorders. Special instruments for engineering investigations.

12. Cabinets Housing the Computer Circuitry with an Attached Programmer's Desk and Typewriter, also a Paper Tape Reader and Punch. These are used to carry out any major alterations or additions to computer instructions (programmes) that may be required.



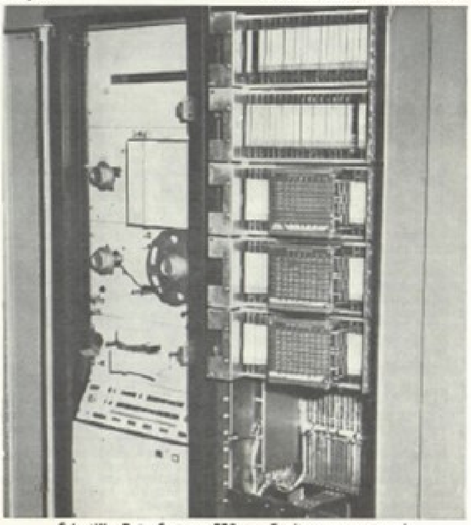
General view of Computer Input/Output Cabinet.

● The Computer Itself

The main component of the data logging system is a SDS 920 Computer, manufactured by Scientific Data Systems Corp. of California.

This is a very powerful computer and the following is a summary of its main statistics:

(CONTINUED ON PAGE 6)



Scientific Data Systems 920 — Ferrite core memory is in section at right.

COMPUTER FOR MUNMORAH

FROM PREVIOUS PAGE

- **Size of Memory:** 12,288 words in ferrite cores; 166,000 words on magnetic drum, each word being 24 bits long.
- **Number of Inputs Handled From Plant:** Maximum of 1400 analog inputs. Maximum of 1064 digital inputs.
- **Scanning Speed:** 120 analog inputs a second maximum; 180,000 digital inputs a second.
- **Calculation Speed:** Fixed point addition—16 microsec. Fixed point multiplication—32 microsec.

(Microsec—millionth of a second.)

● Points Checked by Computer

There will be over 600 measurements made on each unit of temperatures, pressures, flows, levels, etc. and these will be transmitted to the computer in the form of analog electrical signals.

Approximately 160 sets of contacts will be scanned by the computer for either "open" or "closed" status.

In addition, there will be a few pulse generators used for metering the generator output and certain flows, and the pulses from these generators will be received and counted by the computer.

The measurements mainly consist of temperatures, pressures, flows and levels throughout the plant. The largest groups are associated with the temperatures of steam and water, the temperatures of bearings and the temperatures of motor alternator and transformer windings. The majority of the contacts scanned (or digital inputs) are associated with establishing the status of valves, dampers or circuit breakers.

● How Often Does It Check?

The computer does not read or see all the inputs continuously but only one input at a time. When the reading of an input is completed, the computer reads the next sequential input on its scanning list and so on until all inputs have been scanned after which the process is repeated over and over again.

However, the time taken to read one analog input is so short (only eight milliseconds) that it is possible to read all the inputs on both units and still limit the time interval between successive reading of the same input to 60 seconds or less in the case of more important points.

The frequency with which inputs are scanned can be adjusted to suit various purposes, and the following frequencies (scan cycles) are available:—

Point scanned every 60, 30, 12, 6, 3, 2, 1 seconds.

The 1 and 6 second scan frequencies are used for key measurements such as levels, main steam flows, unit load, etc.

The scanning of digital inputs (contact closures) is much simpler as the computer has only to find out whether the circuit is open or closed. Consequently, this is done at high speed and 24 inputs are scanned simultaneously.

The computer will help to ensure that Munmorah Power Station will be one of the most reliable and efficient in Australia.

Page 6 • Network, June, 1966

Figure 7 "Computer for Munmorah" Network JUne 1964 pp 5-6

Plasma Ignition

Pacific Power developed the Plasma Ignition System, first as a test facility at Wangi and Wallerawang and then in the 1990s as a fully operational component at Munmorah. This technology aimed to investigate the replacement of fuel oil or gas firing on pulverised coal fired boilers.[13] Traditionally, fuel oil and/or gas firing had been used for three purposes:

1. To bring the boiler into service from cold in a gradual and controlled manner;
2. To provide a source of ignition for the main pulverised coal burners;
3. To stabilise combustion during load changes and low load operation.

Munmorah's Unit 3 was allocated to the Plasma Ignition System.[14] The system included a Fabric Filter unit to collect Pulverised Fuel (PF) from the Unit 3D Mill, a 120 tonne PF Storage Silo, PF Injectors, a nitrogen sealing system. The single elevation of plasma guns were positioned below the elevations of PF burners.

The plant designers were also mindful that the storage of large quantities of pulverised fuel was not without inherent issues namely spontaneous combustion and gas explosions – both of which did occur despite the nitrogen sealing system. The plant was used successfully over an extended period of time, however, the capital expenditure costs, the plasma ignition electrics, and boiler flame monitoring, were some large obstacles to overcome. It is understood that this system was available until the station closed. Loads as low as 35 MW were achieved for extended periods.[15] Overall, the plasma system had a 70 MW load capacity with unit start-up costs being miniscule compared to fuel oil.

The technology has been adopted by many Chinese authorities for both existing and new boilers. energy-tech.com notes that:

Chinese installations focused on fuel oil displacement as a key feature of the technology. Applications started with single elevation of existing oil-fired ignitors to be replaced with plasma technology. One of many installations was demonstrated in 2006 at Huaneng Yuhuan 1,000 MW unit, where the technology was successful in system start-up from a cold start. The ultimate application was to provide an oil free power plant, eliminating the fuel oil system, using plasma technology for all elevations of ignitors on the boiler. The concept was successfully demonstrated in 2008 at the new 2x600 MW Guodian Kangping Plant, where no fuel oil system was included in the design. [16]

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[13] P. Vierboom, Foreman, C.,, "Boiler Ignition Using Pulverised Coal" (paper presented at the 1996 National Conference on Bulk Materials Handling, Melbourne, 30 September 1996). Interviewee S, Personal Communication with author, 27 January 2017.

[14] Interviewee P, Personal Communication with author, 22 September 2016, 2 January 2017.

[15] P. Vierboom, Hauck, C., Xie, Q.,, "Plasma ignition technology for pulverized coal boilers : A competitive edge in pulverized coal power generation," http://www.energy-tech.com/steam/article_777d4725-1b0b-530c-a994-4d9251a7647e.html. [Accessed 28 January 2017].

[16] ———, "Plasma ignition technology for pulverized coal boilers : A competitive edge in pulverized coal power generation" [Accessed 28 January 2017].

Carbon Capture Pilot Plant

The post-combustion Carbon Capture Pilot Plant was a joint research project between the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Department of Resources and Energy and Delta Electricity. The plant was supported through the Asia-Pacific Partnership on Clean Development and Climate.[17] The plant was commissioned in 2008 and the research program commenced in February 2009.

Figure 8 Munmorah / CSIRO Carbon Capture Plant

Post-combustion capture (PCC) was the first stage in the process of carbon dioxide capture and storage. Amine-based liquid absorbents, including ammonia, (which was used at Munmorah) capture CO_2 and sulphur dioxide (SO_2) from the flue gases before it is emitted to the atmosphere.

The pilot plant trials confirmed the technical feasibility of the ammonia-based capture process and some of expected benefits. CO_2 removal efficiency of more than 85% was achieved.[18] Although not carried out at Munmorah, the captured CO_2 product is pure enough that it is ready for compression, transport and storage.

The Munmorah Pilot Plant received flue gas from Unit 3 Induced Draft (ID) fan discharge and discharged downstream into the stack intake. Unit 3 also provided steam to strip the ammonia back out of the flue gas for reuse. The plant was capable of removing approximately 3,000T of CO2. Dependent on the success of trials geo-sequestration investigations, and ongoing funding, a development plant capable of removing 100,000T was the next step coupled with transport and storage trials at a selected site (Munmorah and Vales Point geology was not suitable for substantial drilling field work). With the closure of Munmorah, the plant was relocated to Vales Point. However, changed political and policy imperatives changed, and funding was not forthcoming to progress the Vales Point trials.

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[17] Interviewee P, Personal Communication with author, 22 September 2016, 2 January 2017. Paul H.M. Feron, *Assessing Post-Combustion Capture for Coal-fired Power Stations in Asia-Pacifi c Partnership Countries: Final report to the Department of Resources, Energy and Tourism* (Newcastle: CSIRO Advanced Coal Technology, 2012). 24.

[18] ———, *Assessing Post-Combustion Capture for Coal-fired Power Stations in Asia-Pacifi c Partnership Countries: Final report to the Department of Resources, Energy and Tourism*: 30.

Social and community:

Many of the people who worked at Munmorah retain a fondness for the station and their time there that in many instances was not evident at earlier or later Electricity Commission power stations. Many people had been at the station from its earliest days and had established an intangible relationship with the station. Defining and analysing this relationship, this 'fondness,' is a very subjective exercise. It cannot be defined in numerical terms; people often use different words, or forms of expression to explain their relationship with the station and their work colleagues.

Many of the people interviewed for this project and the companion 50th Anniversary history, commented on Munmorah being a happy place to work; that there did not seem to be significant division between workgroups or between employees and management. Equally important, the employee Sports and Social Club was very strong and was actively supported by both management and employees. Lunch-time sporting activities, such as Volley Ball and fun runs contributed to a favourable workplace.

Two brief community related examples also provide an insight into the genesis of this regard for the station. Both relate to non-work related aspects of Munmorah.

The first relates to *Camp Breakaway*, a not-for-profit chartable organisation located High View Avenue, San Remo. *Camp Breakaway* was established in 1982 specialising in providing respite care for people with disabilities and their carers.[19]. The Electricity Commission donated a portion of Munmorah's buffer zone to establish this facility.

The second relates to *Koala Park* that is located off the power station entrance road. Many employees considered this facility as one of the benefits of their time at the station. As with *Camp Breakaway*, *Koala Park* is located on power station land, but remained owned by the station. Once the station closed in the early 2010s, the park was leased to Wyong Council for 99 years. In it hey-day, *Koala Park* was the venue for many of the station's social events. Most notable of these was the annual Children's Christmas Party that was run by the Munmorah Sports and Social Club. *Koala Park* was developed by the Sports and Social Club with generous financial and in-kind assistance from the station's management.

Rarity: n/a

Components

Components of Munmorah Power Station were mostly standard equipment for power generation in the 1960s when the plant and equipment were ordered. Exceptions included:

Down-firing boiler: Unlike Vales Point A, Pulverised Fuel was admitted to the top of the boiler's combustion chamber. Further research is required to determine the background to the decisions to install this configuration. All subsequent Electricity Commission power stations utilised the standard bottom fired configuration

Representativeness:

Munmorah Power Station was representative of Electricity Commission of New South Wales power stations commissioned between 1961 (Vales Point A) and the early 1970s (Liddell). These power stations (200 MW to 500 MW) constitute the organisation first major

[19] "Camp Breakaway - Overview," Camp Breakaway Inc., http://www.breakaway.org.au/about/overview. [Accessed 1 December 2016].

construction program. The second involved the commissioning of twelve 660 MW generating units between 1978 and 1994.

Integrity/Intactness:

Munmorah Power Station is in the process of being demolished.

Statement of Significance:

The first generating unit at Munmorah Power Station was commissioned in February 1967, the fourth and final unit in October 1969. The station was the Electricity Commission's response to high single digit and in some year's double-digit increase in the state's annual demand for electricity. Munmorah along with the earlier Vales Point and the later Liddell and Wallerawang C, constituted the Electricity Commission's first major power station construction program.

While these three power stations utilised similar basic power generation technologies and processes, Munmorah incorporated a number of engineering innovations. These included down-fired boilers, all electric controls and computerised monitoring.

Throughout much of its four-decade productive life Munmorah provided reliable base load service. In 1974, it contributed 23% of the total energy generated by NSW coal-fired power stations during the year. As larger, more efficient power stations were commissioned Munmorah's contribution declined.

While many ex-Munmorah employees have fond opinions of the station, it is important to appraise its production record in the context of the state's demand for electricity, and the production records of stations that preceded it as well as those commissioned after it. In the context of The Electricity Commission's overall generation portfolio, Munmorah, while contributing to the burgeoning demand for electricity was nevertheless relatively quickly overtaken by Liddell as the organisation's premier power station. Munmorah's fourth 350 MW unit was commissioned in October 1969 bringing the station's output to 1400 MW. Yet, three years later in December 1972, Liddell's became the Commission's largest station with the commissioning of a third 500 MW unit.[23]

Area of Significance

State.

[23] *Electricity Commission of New South Wales / Pacific Power Annual Reports 1953 - 2000.*

Image(s) with caption:

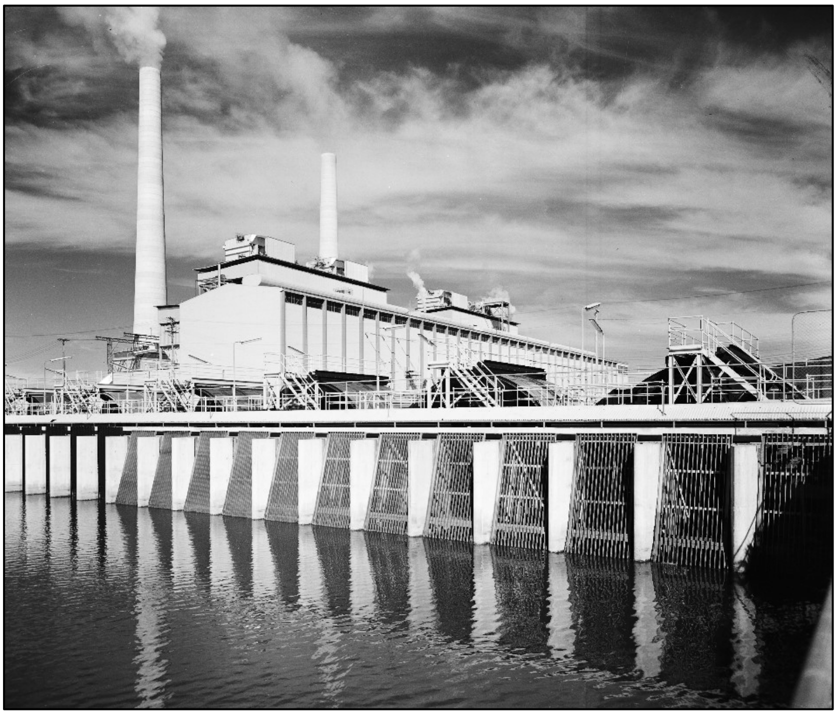

Figure 9 Munmorah External - (ECNSW 09270)

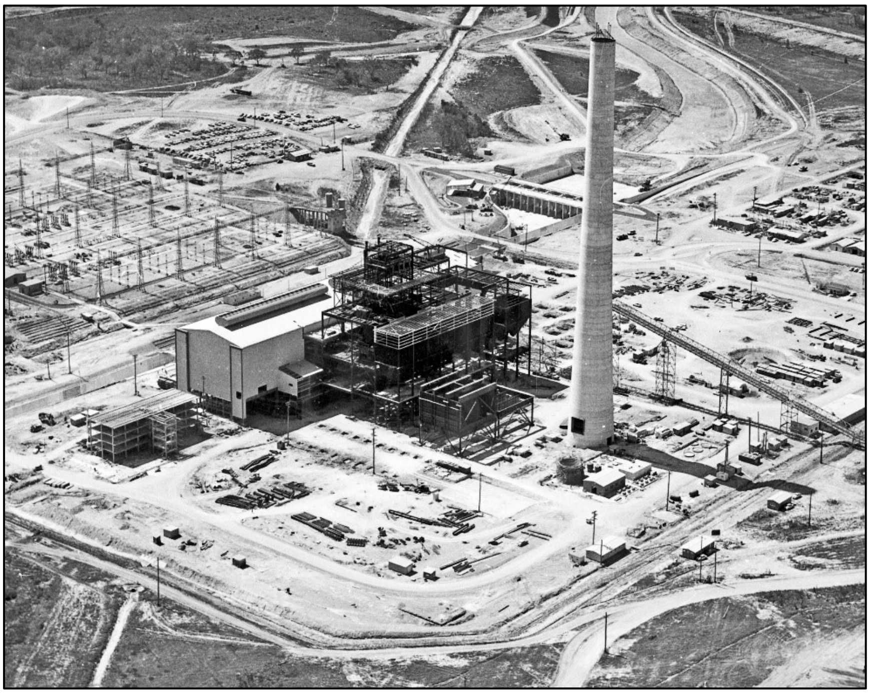

Figure 10 Munmorah - March 1965 - (ECNSW 05457)

Figure 11 Munmorah Coal Storage Area - February 1967 (ECNSW 07044)

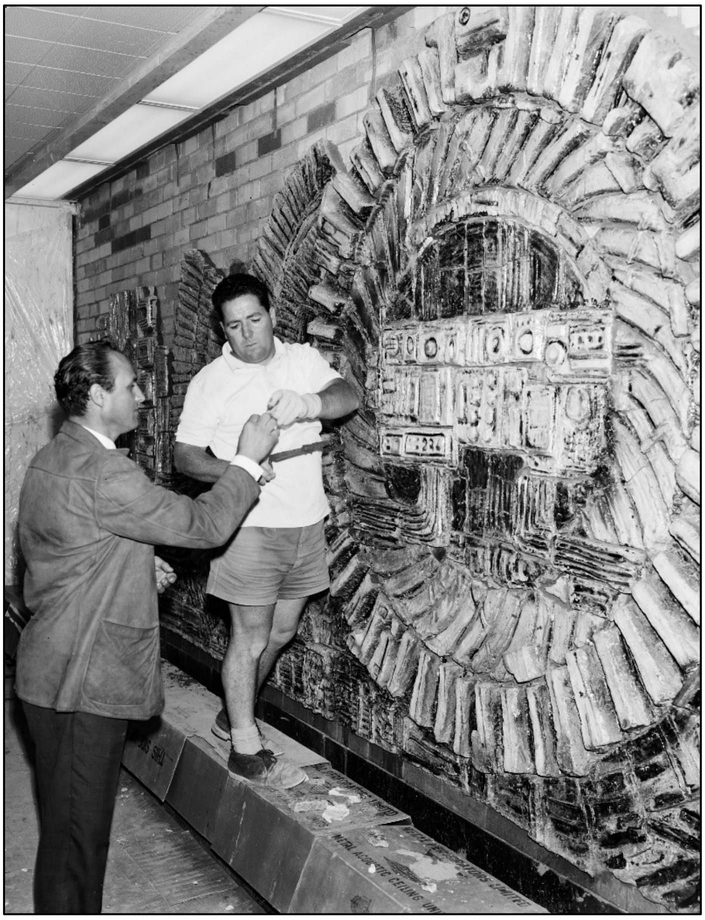

Figure 12 Installation of Munmorah Mural in Administration Building Foyer (ECNSW 07129)

Figure 13 Munmorah for *Opening Souvenir Book* (ECNSW 09270)

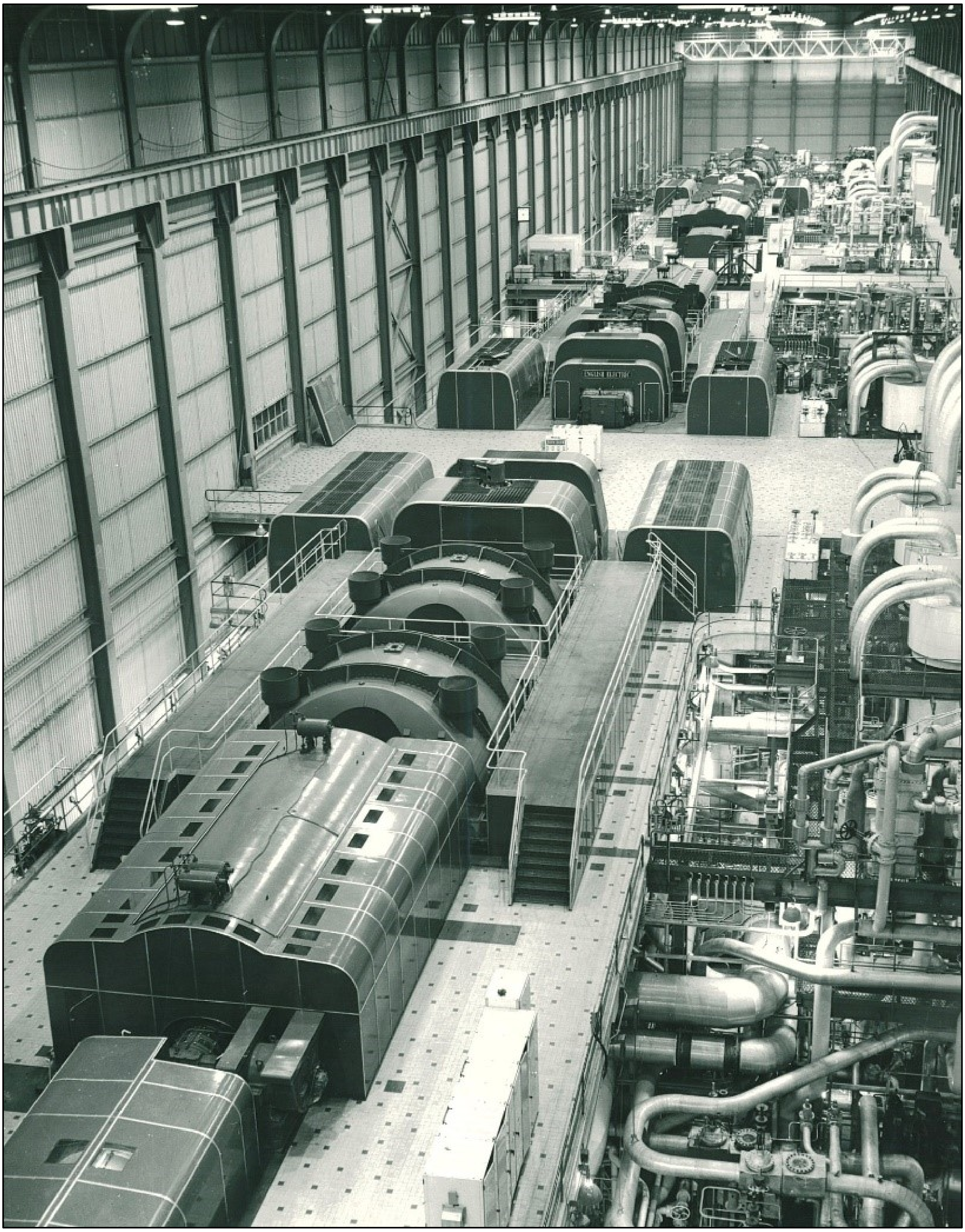

Figure 14 Munmorah Turbine Hall for *Opening Souvenir Book* (ECNSW 09270)

Figure 15 Munmorah Steam Piping for *Opening Souvenir Book* (ECNSW 09270)

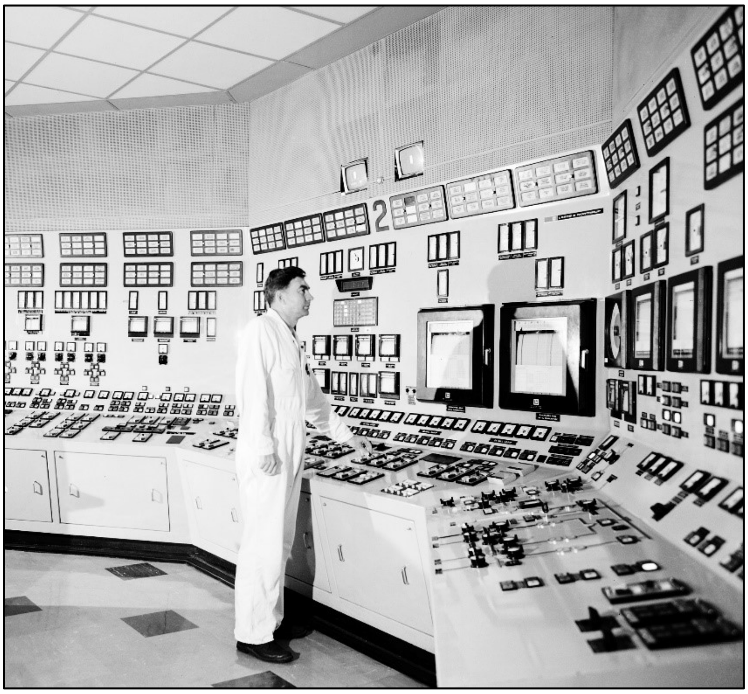
Figure 16 Munmorah 1/2 Plant Control Room for *Opening Souvenir Book* (ECNSW 09270)


Figure 17 Munmorah Computer Equipment for *Opening Souvenir Book* (ECNSW 09270)

Figure 18 Unit 3 Turbine and Electrical Control Panels following upgrade in the early 1990s. (Courtesy of …)

Appendix 1 Boiler Performance Data at Continuous Rating[20]

TYPE: "LOPULCO" DOWNDRAUGHT CONTROLLED CIRCULATION REHEAT FULLY WATER COOLED

Evaporation	309.0	kg/sec
Final Superheater Outlet Pressure	16,500	kPa
Final Superheater Outlet Temperature	565^{0}C	
Feed Water Temperature - Economiser Inlet	255^{0}C	
Feed Water Temperature - Economiser Outlet	288^{0}C	
Reheat Steam Flow	244	kg/sec
Reheat Inlet Pressure	4,334	kPa
Reheat Inlet Temperature	371^{0}C	
Reheat Outlet Pressure	4,093	kPa
Reheat Outlet Temperature	540^{0}C	
Efficiency (Gross CV)	89.6	%
Furnace Gas Exit Temperature	$1{,}196^{0}$C	
Secondary Superheater Gas Exit Temperature	$1{,}038^{0}$C	
Reheater Gas Exit Temperature	838^{0}C	
Economiser Gas Inlet Temperature	449^{0}C	
Economiser Gas Exit Temperature	321^{0}C	
Air Heater Gas Exit Temperature	129^{0}C	
Air Heater Air Exit Temperature	252^{0}C	
CO_2 at Furnace Exit	15.9	%
CO_2 at Air Heater Exit	14.6	%

[20] *Boiler General Description*, ed. Geoff Byrant, Munmorah APPO School Manual (Munmorah Power Station: Delta Electricity, 2004).

Appendix 2 – Performance Statistics

Thermal Efficiency

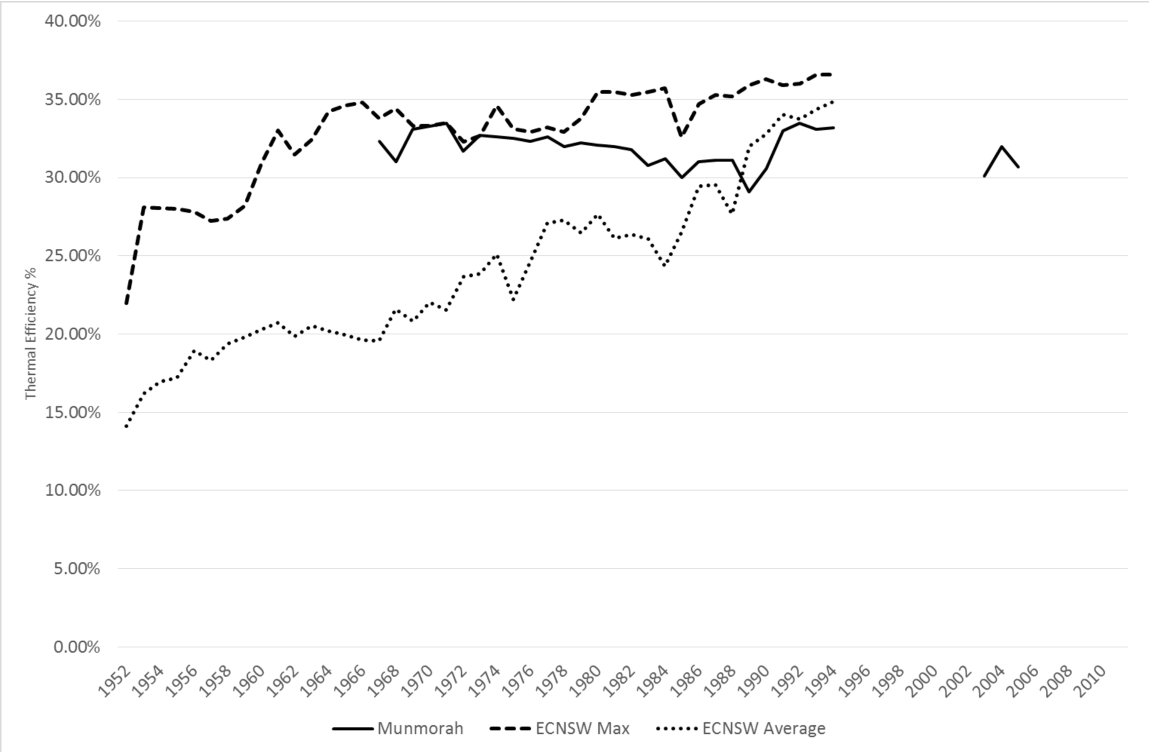

Figure 19 NSW Power Station Thermal Efficiency 1952 - 20010

Availability

Capacity Factor

Employee Numbers

Appendix 3 Generating Plant installed in power stations operated by the Electricity Commission of New South Wales: May 1950, 30 June 1980 and 30 June 1994.

Table 1 Generating plant installed in power stations on the NSW interconnected System at May 1950.

THE ELECTRICITY COMMISSION OF NEW SOUTH WALES.

GENERATING PLANT INSTALLED IN POWER STATIONS ON NEW SOUTH WALES INTERCONNECTED SYSTEM AT MAY, 1950.

Generating Authority.	Power Station.	Turbo Alternator Plant.				Boiler Plant.			
		No. of Machines.	Rating. mW.	Year first Installed.	Total Rating.	No. of Units.	Rating. lb./hr.	Year first Installed.	Total Rating.
Southern Electricity Supply	Port Kembla	1	5	1925	5	1	20,000	1926	20,000
,, ,, ,, ...	,, ,, ...	1	3	1928	3	1	40,000	1928	40,000
,, ,, ,, ...	,, ,, ...	1	5·5	1938	5·5	1	50,000	1938	50,000
,, ,, ,, ...	,, ,, ...	1	7·5	1941	7·5	1	60,000	1938	60,000
,, ,, ,, ...	,, ,, ...	1	7·5	1946	7·5	1	75,000	1941	75,000
		Total Power Station Installation			*28·5*	1	85,000	1946	85,000
,, ,, ,, ...	Burrinjuck Hydro	2	5	1927	10				
,, ,, ,, ...	,, ,, ...	2	5	1938	10				
		Total Power Station Installation			*20*				
,, ,, ,, ...	Wyangala Hydro	1	7·25	1947	*7·25*				
,, ,, ,, ...	Cowra	1	5	1925	*5*	3	25,000	1944	75,000
,, ,, ,, ...	Canberra	2	1·5	1919	*3*	2	40,000	1921	80,000
						2	20,000	1939	40,000
,, ,, ,, ...	Yanco	1	0·75	1926	0·75	1	10,000	1926	10,000
,, ,, ,, ...	,, ...	1	0·75	1927	0·75	1	10,000	1936	10,000
,, ,, ,, ...	,, ...	1	0·75	1931	0·75	1	35,000	1936	35,000
,, ,, ,, ...	,, ...	1	2·5	1936	2·5	1	10,000	1937	10,000
		Total Station Installation			*4·75*				
Sydney County Council	Pyrmont " A " ...	2	12	1921–22	24	4	80,000	1921–22	320,000
,, ,, ,, ...	,, ...	1	8	1921	8	4	80,000	1923–24	320,000
,, ,, ,, ...	,, ...	1	17·5	1924	17·5				
		Total Station Installation			*49·5*				
,, ,, ,, ...	Bunnerong " A "...	2	1·5	1929	3*	12	120,000	1929	1,440,000
,, ,, ,, ...	,, ...	6	25	1929–30	150	6	120,000	1930	720,000
,, ,, ,, ...	,, ...	1	25	1937	25				
		Total Station Installation			*178*				
,, ,, ,, ...	Bunnerong " B "...	1	50	1939	50	1	350,000	1939	350,000
,, ,, ,, ...	,, ...	1	50	1941	50	3	350,000	1941	1,050,000
,, ,, ,, ...	,, ...	1	50	1947	50				
		Total Station Installation			*150*				
Department of Railways	White Bay	2	22	1925	44	5	70,000	1925	350,000
,, ,, ...	,, ,, ...	1	22	1926	22	1	70,000	1926	70,000
,, ,, ...	,, ,, ...	1	18·75	1928	18·75	5	110,000	1926	550,000
,, ,, ...	,, ,, ...	1	20	1928	20	4	110,000	1927	440,000
		Total Station Installation			*104·75*				
,, ,, ...	Ultimo	1	20	1927	20	2	110,000	1930	220,000
,, ,, ...	,, ...	2	20	1930–31	40	4	110,000	1931	440,000
,, ,, ...	,, ...	1	20	1941	20	2	110,000	1941	220,000
		Total Station Installation			*80*				
,, ,, ...	Zara-st., Newcastle	1	7·5	1920	7·5	2	40,000	1915	80,000
,, ,, ...	,, ,, ...	1	7·5	1924	7·5	1	40,000	1916	40,000
,, ,, ...	,, ,, ...	1	7·5	1928	7·5	1	40,000	1923	40,000
,, ,, ...	,, ,, ...	1	7·5	1936	7·5	1	40,000	1927	40,000
,, ,, ...	,, ,, ...	1	12·5	1940	12·5	1	45,000	1930	45,000
,, ,, ...	,, ,, ...	1	20	1942	20	2	40,000	1930	80,000
,, ,, ...	,, ,, ...	1	15	1946	15	2	150,000	1939	300,000
		Total Station Installation			*77.5*	2	150,000	1946–47	300,000
,, ,, ...	Lithgow	2	2·5	1928	5	2	70,000	1925	140,000
,, ,, ...	,, ...	1	2·5	1932	2·5	1	47,500	1926	47,500
,, ,, ...	,, ...	1	7·5	1948	7·5	2	31,250	1927–28	62,500
		Total Station Installation			*15·0*	1	31,250	1931	31,250
Electric Light and Power Supply Corporation	Balmain	1	9	1923	9	1	45,000	1926	45,000
,, ,, ,, ...	,, ...	1	12	1928	12	1	45,000	1928	45,000
,, ,, ,, ...	,, ...	1	18·75	1936	18·75	1	45,000	1932	45,000
,, ,, ,, ...	,, ...	1	9·4	1946	9·4	1	70,000	1935	70,000
		Total Station Installation			*49·15*	1	100,000	1937	100,000
						1	125,000	1945	125,000
						1	125,000	1946	125,000

Table 2 Generating Plant installed at 30 June 1980

GENERATING PLANT Installed at 30th June, 1980

Power Station	Turbo-Alternator Plant				Boiler Plant			
	No.	Rating MW	Year Installed	Total Rating MW	No.	Rating kg/s	Year Installed	Total Rating kg/s
STEAM Base Load Plant Liddell	4	500.0	1-1971 2-1972 1-1973	2000	4	453.6	1-1971 2-1972 1-1973	1814
Munmorah	4	350.0	1-1967 1-1968 2-1969	1400	4	308.7	1-1967 1-1968 2-1969	1235
Vales Pt. 'B'	2	660.0	1-1978 1-1979	1320	2	560.7	1-1978 1-1979	1121
Wallerawang 'C'	1	500.0	1976	500	1	453.6	1976	454
Total Base Load Plant	11			5220	11			4624
Intermediate Load Plant Tallawarra 'B'	2	100.0	1-1960 1-1961	200	2	104.6	1-1960 1-1961	209
Vales Pt. 'A'	3 1	200.0 275.0	1-1963 1-1964 1-1965 1966	875	3 1	170.1 233.1	1-1963 1-1964 1-1965 1966	743
Wallerawang 'B'	2	60.0	1961	120	2	69.3	1961	139
Wangi 'B'	3	60.0	1-1958 1-1959 1-1960	180	3	69.3	2-1959 1-1960	208
Total Intermediate Load Plant	11			1375	11			1299
Peak Load Plant Tallawarra 'A'	4	30.0	1-1954 1-1955 1-1956 1-1957	120	4	37.8	1-1954 1-1955 1-1956 1-1957	151
Wallerawang 'A'	4	30.0	1-1957 2-1958 1-1959	120	4	37.8	1-1957 2-1958 1-1959	151
Wangi 'A'	3	50.0	1-1956 2-1957	150	6	31.5	2-1956 3-1957 1-1958	189
Total Peak Load Plant	11			390	14			491
Plant Capable of Operation in Emergencies Muswellbrook	2	15.0	1-1959 1-1960	30	2	21.4	1-1959 1-1960	43

GENERATING PLANT Installed at 30th June, 1980

Power Station	Turbo-Alternator Plant				Boiler Plant			
	No.	Rating MW	Year Installed	Total Rating MW	No.	Rating kg/s	Year Installed	Total Rating kg/s
Pyrmont	4	50.0	1-1952 1-1953 1-1954 1-1955	200	4	54.2	1-1952 1-1953 1-1954 1-1955	217
White Bay	2	50.0	1-1951 1-1956	100	4	28.4	1-1951 1-1952 2-1958	114
Total Plant Capable of Operation in Emergencies	8			330	10			374
TOTAL STEAM	41			7315	46			6788
HYDRO-ELECTRIC								
Brown Mountain	1 2 2	0.45 0.75 1.0	1943 1953 1957	4				
Burrinjuck	2	5.0	1938	10				
Hume	2	25.0	1957	50				
Keepit	1	6.0	1960	6				
Shoalhaven	2 2	40.0 80.0	1977 1977	240				
Warragamba	1	50.0	1959	50				
TOTAL HYDRO	15			360				
INTERNAL COMBUSTION								
Broken Hill	4 5 3 3 2 1 1	1.28 0.92 2.84 4.45 1.40 1.0 2.0	1958 3-1958 2-1961 1965 2-1970 1-1973 1976 1977 1977	37				
Total Internal Combustion	19			37				
GAS TURBINES								
Liddell	1	12.0	1971	12				
Munmorah	1	12.0	1971	12				
Total Gas Turbines	2			24				
TOTAL ALL STATIONS	77			7736	46			6788

Table 3 Generating Plant 30 June 1990

Table 3 Generating Plant

Power Station	Turbo-Alternator Plant No.	Turbo-Alternator Plant Rating MW	Turbo-Alternator Plant Year Installed	Boiler Plant No.	Boiler Plant Rating kg/s	Boiler Plant Year Installed	Station Maximum Dependable Capacity MW
Steam Base Load Plant Bayswater	4	660.0	2-1985 2-1986	4	590.0	2-1985 2-1986	2 640
Eraring	4	660.0	2-1982 1-1983 1-1984	4	590.0	2-1982 1-1983 1-1984	2 640
Liddell	4	500.0	1-1971 2-1972 1-1973	4	453.6	1-1971 2-1972 1-1973	2 000
Munmorah	4	300.0	1-1967 1-1968 2-1969	4	308.7	1-1967 1-1968 2-1969	1 200
Vales Point "B"	2	660.0	1-1978 1-1979	2	560.7	1-1978 1-1979	1 320
Wallerawang "C"	2	500.0	1-1976 1-1980	2	441.0	1-1976 1-1980	960
Total Base Load Plant	20			20			10 760
Dry Stored Plant							
Tallawarra "B"	2	100.0	1-1960 1-1961	2	104.6	1-1960 1-1961	
Vales Point "A"	3 1	200.0 250.0	1-1963 1-1964 1-1965 1-1966	1 2 1	170.1 170.1 233.1	1-1963 1-1964 1-1965 1-1966	
Total Dry **Stored Plant**	6			6			

Table 3 Continued

Power Station	Turbo-Alternator Plant No.	Rating MW	Year Installed	Boiler Plant No.	Rating kg/s	Year Installed	Station Maximum Dependable Capacity MW
Hydro-electric							
Brown Mountain	1	0.45	1943				
	2	0.75	1953				
	2	1.0	1957				4
Burrinjuck	2	5.0	1938				10
Hume	2	25.0	1957				25*
Keepit	1	6.0	1960				6
Shoalhaven	2	40.0	1977				
	2	80.0	1977				240
Warragamba	1	50.0	1959				50
Total Hydro-electric	15						335
Gas Turbines							
Peak Load							
Broken Hill	2	25.0	1989				50
Hunter Valley	2	25.0	1988				50
Koolkhan	1	25.0	1982				
	3	23.4	1982				95
Northern	4	25.0	1982				100
Capable of operation in emergencies							
Liddell	1	12.0	1971				
Munmorah	1	12.0	1971				
Total Gas Turbines	14						295
Total All Stations	95			54			11 390

*NSW share

Table 4 Generating Plant 30 June 1994

Table 3
Generating Plant

	Turbo Alternator Plant			Boiler Plant			Station
Power Station	**No.**	**Rating MW**	**Year Installed**	**No.**	**Rating kg/s**	**Year Installed**	**Maximum Dependable Capacity MW**
Steam							
Base Load Plant							
Bayswater	4	660	2-1985	4	590.0	2-1985	2640
			2-1986			2-1986	
Eraring	4	660	2-1982	4	590.0	2-1982	2640
			1-1983			1-1983	
			1-1984			1-1984	
Liddell	4	500	1-1971	4	453.6	1-1971	2000
			2-1972			2-1972	
			1-1973			1-1973	
Mount Piper	2	660	1-1992	2	590.0	1-1992	1320
			1-1993			1-1993	
Munmorah	2	300	2-1969	2	308.7	2-1969	600
Vales Point "B"	2	660	1-1978	2	560.7	1-1978	1320
			1-1979			1-1979	
Wallerawang "C"	2	500	1-1976	2	441.0	1-1976	1000
			1-1980			1-1980	
Total Base Load Plant	20			20			11520
Dry Stored Plant							
Munmorah	2	300	1-1967	2	308.7	1-1967	
			1-1968			1-1968	
Total Dry Stored Plant	2			2			
Hydro-electric							
Brown Mountain	1	0.45	1943				4
	2	0.75	1953				
	2	1.00	1957				
Burrinjuck	2	5.00	1938				10
Hume	2	25.0	1957				*25
Keepit	1	6.00	1960				6
Shoalhaven	2	40.0	1977				
	2	80.0	1977				240
Warragamba	1	50.0	1959				50
Total Hydro-electric	15						335
Gas Turbines							
Peak Load							
Broken Hill	2	25.0	1989				50
Hunter Valley	2	25.0	1988				50
Koolkhan	1	25.0	1982				
	3	23.4	1982				95
Northern	4	25.0	1982				100
Capable of Operation in Emergencies							
Liddell	1	12.0	1971				
Munmorah**	1	12.0	1971				
Total Gas Turbines	14						295
Total Commissioned All Stations	50			22			12150

* NSW Share

** Work required before operational - decommissioning in progress.

Appendix 4 Burra Charter and the Heritage Assessment of NSW Power Stations

Of the *Burra Charter's* three broad procedural guidelines, understanding significance; develop a policy; and manage the conservation of an item, the ECNSW implemented the first for a number of its power stations – Ultimo, White Bay, Balmain, Pyrmont, Bunnerong Switch House, Vales Point 'A', Wangi, Penrith, Lithgow and Wallerawang 'A' and 'B'.[21] The recommendations of the subsequent heritage reports were varied, and ranged from the retention of heritage buildings and a representative 'slice' of generation equipment (White Bay); adaptive reuse as a means of conserving the buildings and grounds (Wangi, Ultimo, Pyrmont 'A' Admin Building, Bunnerong Switch House and Penrith), to not recommended for conservation (Pyrmont 'B', Balmain, and Vales Point 'A'). Similar studies have not been undertaken for Munmorah or Liddell. Given Vales Point 'A' was not recommended for retention, it is likely that a heritage study of Munmorah or Liddell, if carried out, would come to a similar recommendation.

[21] Ken Thornton and Mark Fetscher, "Liddell Power Station: has a good heart – but needs support and prudent asset management at its end of life" (paper presented at the 18th Australian Engineering Heritage Conference 2015 Newcastle, 7– 9 December 2015).

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